Lecture 3   Historical/Technical Analyses of Engineering Systems

3 different approaches to thinking about the topics of this course are things you want to ask as you read the assignments:
Who's the author? What's his primary function? What is he writing *against?*

Vincenti:
"Design Knowledge": what does he mean by this?
- In part, he means taking specific scientific knowledge and applying it successfully
- Knowledge "that" vs. knowing "how"; understanding the natural science vs. understanding the engineering process that applies the science
- Normal vs. radical design

Engineering Epistemology: what does *this* mean?
- "epistemology" = theory of knowledge
- what counts as knowledge in engineering? It may change at any time. For example:
  o "CDIO," course 16's motto: "conceive, design, implement, operate."
  o Creation of ESD at MIT; recognition that systems-level knowledge is important.
  o Practical experience: in the context of Apollo, there was almost no practical experience – there had been Mercury, but not much else. Whenever we do have prior experience to draw upon, that's great, but we must make sure not to just draw rote from the handbook; innovative ideas are also important.
  o Simulation (recent addition); before we could do computer simulations, you actually had to create the real thing and test it.

What are the political and social implications of understanding the division between the conception and design, and the implementation, of a project?
- acknowledgment of success usually goes to the C/D people; complaints go to the I/O people
- no credit ever seems to go to the contractors and skilled craftsmen who actually built the spacecraft – it's really no small task to successfully implement a very difficult design
- there's a sense that it's the contractors' jobs to make their customers look good
- during Apollo, both sides felt they knew more than the other
- at the time of Apollo, there wasn't yet the modern sense of "design for manufacturability"
- making changes on the production lines is actually kind of a terrible thing to do, because they may have a ripple effect out to other systems. Even if you go through the right channels, what happens is that you get a bunch of change orders and the design basically has to be redone. So, "don't innovate". (Scranton)

"Failure is your friend" (Scranton): young engineers are frustrated by failure during testing, but when that happens, that means you're that much closer to figuring out how to make it really work when you really need it to.

Tension running through these large programs: how do you create a project with a reasonable amount of certainty in how it should work, while accommodating all the little things that go wrong, which all potentially mean you should change how you're thinking about it? Military motto: "no plan survives contact with the enemy." This isn't usually how civilian projects are run.

[clip from Tom Hanks' *From the Earth to the Moon*; "Tom Kelly"]
What can we say about this design process?
- "iteration"
- went from normal designs to more radical designs as time went on, especially since Grumman specialized in landing gear; everything beyond that was out of their native waters
    o They moved out of "science fiction" - idealized, simpler forms - to a more complex, much more unexpected design
- they use physical models to discuss the design and sometimes to prove an idea to themselves and colleagues (these days we can use simulations and computer models)
- the film portrays the solution to the problem of having to switch the orientation of the controls while docking the LM to the command module as being "astronauts are smart, they'll figure it out," crediting the success of the operation to human skill. The reality is, it was a fly-by-wire system, and could be reprogrammed for the docking procedure.
- Lots of trade-offs made for weight, complexity, human skill. How do you make trade-offs for *dissimilar* components? It's harder, and part of the larger systems-level engineering.

Some guys from Grumman mistakenly thought that one particularly intimidating guy (from NASA proper) had an MIT ring, but he didn't. They just associated the feeling of intimidation with the presence of an MIT rat!

Historiography (Launius reading)
- means to write about how the historical story is told
- foreign and public policy: major work is John Logston's book, *The Decision to Go to the Moon*. Why are the politicians interested in this project? (Logston will come to speak to the class later in the term.) How does a political entity link up to a technical apparatus?
    o It's said there are two major types of critiques of Apollo and the space program: the liberal and conservative critiquies. Liberal: why spend so much money on this when we could be helping our inner cities/easing other social problems? Conservative: why are we spending so much money on something that's not a well-defined, typical government program (such as defense)?

- space hardware ("nuts and bolts," "fetish for the artifact"): intricate hardware; related to the thought that "this isn't hardware, it's jewelry" – every piece was important, almost art in and of itself.

To be continued next time.